OWMC

Ontario Waste Management Corporation

FINAL REPORT

Gartner Lee Associates Limited

Engineering Geologists, Hydrogeologists, Biologists,
Environmental Consultants

HYDROGEOLOGIC CONSIDERATIONS
FOR
FACILITIES SITING

FOR

ONTARIO WASTE MANAGEMENT CORPORATION

BY

GARTNER LEE ASSOCIATES LIMITED

PROJECT NO. 83-1002

MAY, 1983

Gartner
Lee
Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

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May 11, 1983.

Ontario Waste Management Corporation,
2 Bloor Street West,
11th Floor,
Toronto, Ontario,
M4W 3E2.

Attention: Dr. B.D. Mitchell,
Director,
Corporate Planning & Development

Dear Sir:

Re: Hydrogeologic Considerations for Facilities Siting - (GLAL 83-1002)

We are pleased to submit our final report entitled "Hydrogeologic Considerations for Facilities Siting" within the Golden Horseshoe.

The objective of this report is to provide the Ontario Waste Management Corporation with guidance for the selection of priority areas of study on the basis of hydrogeology. The hydrogeological considerations required to evaluate the possible effects of contaminant movement within the subsurface are also discussed.

We recommend that those areas of the Golden Horseshoe underlain by the deepest and most consistent deposits of fine-textured soils should have the highest priority of study. Areas underlain by coarser-textured soils should have the lowest priority.

Within the high priority areas, we have further recommended that mapping provide a description of the geologic materials,

continued ..

their continuity and stratigraphic relationships with depth.

We trust that this provides you with our rationale for selection of priority of study from a hydrogeologic perspective and we thank you for this opportunity to be of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.
Project Director.

JPF:jcm
Enclosure.

TABLE OF CONTENTS

	PAGE
1.0 INTRODUCTION	1
2.0 FACILITIES AND WASTE CHARACTERISTICS:	2
2.1 General Considerations	2
2.2 Engineered Landfill	3
2.3 Treatment and Transfer Facilities	4
3.0 HYDROGEOLOGIC CONSIDERATIONS:	6
3.1 Contaminant Movement in the Hydrogeologic Environment	6
3.2 Significance of Contaminant Movement	10
3.3 Hydrogeologic Setting	11
4.0 RECOMMENDATIONS	13
5.0 BIBLIOGRAPHY	16

HYDROGEOLOGIC CONSIDERATIONS FOR FACILITIES SITING

1.0 INTRODUCTION:

This submission summarizes Gartner Lee Associates Limited's input in the matter of hydrogeologic considerations for facilities siting. The objective is to provide the Ontario Waste Management Corporation (OWMC) with guidance for the selection of priority areas of study within the Golden Horseshoe on the basis of hydrogeology. Emphasis is placed on providing siting considerations for the engineered landfill, physical/chemical plant, incinerator, and collection and transfer stations.

From a hydrogeologic perspective, an assessment of facility siting requirements involves evaluation of the combined effect of all of the following:

- type of facility, conceptual design, and operational mode, to gain an appreciation of how and what contaminants would come in contact with the hydrogeologic environment;

- waste and emissions characteristics being handled at each facility, their behaviour in the subsurface, the release rate of waste constituents and thus an appreciation of the probable behaviour of the waste in the subsurface environment;

- site characteristics, particularly the geology, hydrogeology and hydrogeochemistry which govern the quantity of contaminants that can enter the subsurface environment and the direction and rate of contaminant travel.

Although a complete appraisal cannot be developed until waste types, emissions characterization and site specific data from site drilling, testing and monitoring results become available, it is possible to provide some guidance at this time in terms of the significance of the above factors for siting considerations, by making certain assumptions, as outlined in this report.

2.0 FACILITIES AND WASTE CHARACTERISTICS:

2.1 GENERAL CONSIDERATIONS:

Information on the facility characteristics is not presently finalized, although study by others is currently underway. We can, however, make a number of preliminary assumptions that will guide us in developing our hydrogeologic rationale.

We understand that all OWMC facilities will incorporate proven technologies. While it is possible to engineer

safeguards which will greatly reduce the possibility of occurrence of spills or leaks, the OWMC does not wish to rely completely on these engineered systems to protect the environment. While engineered systems will be utilized at all sites, the final defense will be the natural capability of the physical environment to accommodate the possibility of leaks and spills.

Monitoring for contaminant release will be an integral part of all facilities operations and this monitoring will trigger activation of contingency measures. Such contingency planning measures will be aimed at rapid response and clean-up in the event of accidental spills or leaks.

2.2 ENGINEERED LANDFILL:

In a landfill, residues from the treatment processes are intentionally and permanently placed on or below the ground surface. The landfill will accept only treated residues which will be primarily inorganic in nature.

The wastes will be in solid or semisolid form to provide structural integrity of the product and to minimize the production of leachate.

During the disposal operations, wastes will be placed in individual cells of limited capacity. This will help

to ensure that incompatible wastes are isolated from each other, that the wastes are compatible with engineered components such as liners, that the working area is a manageable size and that the facility design can be modified to accommodate future technological advances and contingency plans.

The engineered landfill will be designed to minimize the formation of leachate, to retard migration of any leachate into the surrounding environment and to provide remedial contingency measures, if needed.

In order to realize these design objectives, perpetual maintenance and monitoring of the landfill facility will be required.

2.3 Treatment and Transfer Facilities:

These facilities include the physical/chemical treatment plant, the incinerator and possibly various transfer stations to be established in the Province. Unlike the landfill, raw wastes will be handled, stored and treated at these sites for only a finite length of time, this time being governed by the active life of the facility. No wastes (treated or untreated) will be disposed at these sites unless the facility is fully integrated.

Treatment components and handling methods will be

compatible with the waste streams and will be designed to minimize environmental exposure. Quality and quantity control supervision and monitoring will verify the composition of the waste loads received, determine the appropriate treatment processes and control the quality of processing. Site specific spill containment features could include pads, berms and drainage collection installations.

The physical/chemical treatment facility will handle and treat a wide range of wastes consisting primarily of heavy metal solutions and residuals. However, it has been indicated that oil/water mixtures, organic and oily residuals, and paint and organic residuals could also be treated at the physical/chemical treatment plant.

The organic compounds, following initial treatments, will likely be transferred to the incinerator. The incinerator will handle and treat or destroy primarily organic compounds such as organic and oily residuals, sludges, still bottoms and paints. Metal sludges, slags and residues following treatment could go to the landfill. Treated waste streams would either be discharged to a suitable receiver or transferred to the physical/chemical treatment plant for further processing.

The transfer stations will handle, store and possibly bulk both organic and inorganic wastes.

Data available at the present time indicate that organic

constituents could be present in the liquid effluents from the various facilities. The types and characteristics of the constituent organics is as yet unknown. The treatment processes are presently being assessed as are the emissions characteristics.

3.0 HYDROGEOLOGIC CONSIDERATIONS:

The significance of the various complex and interrelated hydrogeologic and chemical processes which must be considered in siting individual OWMC facilities are discussed in this section. Emphasis is placed on the processes which influence contaminant travel in the subsurface in order to provide the background to understand what could transpire in the event that an accidental discharge of wastes occurred via a leak or spill. While this discussion is general in scope, it does give the technical basis for establishing the priority of study within the Golden Horseshoe.

3.1 CONTAMINANT MOVEMENT IN THE HYDROGEOLOGIC ENVIRONMENT:

Contaminant movement in the subsurface is influenced by a number of processes of varying complexity which are both site and contaminant specific. Those processes

which tend to promote contaminant movement are:

- advection
- hydrodynamic dispersion
  - mechanical dispersion
  - molecular diffusion

Advection refers to the process by which natural chemical constituents dissolved in ground water and/or introduced contaminants migrate in solution (as solutes) in the direction of ground water flow. As with ground water, the rate of movement of these solutes is governed by the change in hydraulic potential (known as the hydraulic gradient) along the path of flow and the characteristics (effective porosity and permeability) of the material through which the ground water and solutes move. For example, ground water movement and hence solute movement is relatively rapid through the pore spaces of coarse textured soils (sand), and very slow through fine textured soils (clay).

Hydrodynamic dispersion is the process whereby solutes (i.e. contaminants) tend to spread out from the path of flow and mix with ground water with lower solute concentrations (i.e. background quality ground water). This spreading results in the dilution of the solute by:

- *mechanical dispersion* - the mixing of solute-rich ground water with solute-deficient ground water, as a result of the physical movement through pore spaces, between soil grains or through fractures;

- *molecular diffusion* - the spreading out of concentrated solute mixtures from a zone of high concentration to those of lower chemical concentrations as a result of the thermal kinetic energy of the solute molecules.

Both mechanical dispersion and molecular diffusion result in a decrease in solute (contaminant) concentration along the path of flow. Mechanical dispersion is associated with advection and occurs during ground water movement, while molecular diffusion is independent of ground water movement and can occur even under stagnant flow conditions or even counter to ground water movement directions or gravity. In the case of fracture flow (advection) in fine-textured materials (clay) some solute can diffuse from the fluid into the soil matrix from the fractures. It follows therefore that advection and mechanical dispersion are the dominant contaminant transport mechanisms when ground water velocities are moderate to rapid such as through sand or gravel. Molecular diffusion is the dominant transport mechanism where flow velocities are very slow, such as through clay.

A number of chemical and biochemical processes act to further reduce chemical concentrations or retard chemical movement along the ground water flow path. These processes, commonly referred to as *attenuation*, include:

- ion exchange - the exchange or replacement of chemical ions held on the surface of clay minerals with ions in the flowing ground water;

- adsorption - the attraction of chemical ions in the ground water onto clay minerals;

- hydrolysis - the alteration of chemical compounds through reaction with the ground water;

- precipitation - the removal of a substance from a solution by chemical change e.g. the formation of an insoluble solid;

- biodegradation - the alteration or complete utilization of chemical compounds and ions by microorganisms;

- volatilization - the vaporization of organic compounds in the shallow subsurface.

Although attenuation takes place in almost all hydrogeologic environments, clay textured geologic materials have the greatest attenuation capability because of ion exchange and adsorption potentials. It should be noted however, that the chemical characteristics of the waste constituents that may potentially migrate in the hydrogeologic environment will play a significant role in determining the amount of attenuation that will take place. For example, chloride ions are considered to be nonreactive; that is, they do not readily attenuate and are only reduced in concentration by hydrodynamic dispersion (dilution). Heavy metals, on the other hand, are reactive and as such are readily adsorbed onto geologic materials and do not normally migrate great distances away from the waste source. Some organic

compounds are extremely persistent and migrate unaffected by chemical processes while others biodegrade, volatilize and are chemically altered.

3.2 Significance of Contaminant Movement:

Advection is the predominant process of contaminant and ground water movement in permeable to moderately permeable, geologic materials, i.e. sandy, gravelly and sandy-silty textured materials. In general, the rate of movement is a function of the effective porosity, hydraulic conductivity and hydraulic gradient. In this type of hydrogeologic setting, the non-reactive ions, such as chloride, will migrate in relation to the modified Darcy Equation, and estimates of their velocity can be calculated. In sands and gravels, movement can be very rapid (tens to thousands of metres per year). In fine textured soils such as clay, however, the movement due to advective flow is extremely slow (less than 0.01 m/a).

Thus, advective flow allows for the rapid movement of ground water and contaminants through the soil mass where the materials have small effective porosities and high hydraulic conductivity. These conditions exist in coarse grained geologic materials such as sands and gravels.

Molecular diffusion becomes important as a contaminant transport mechanism in fine grained soils where the

ground water velocities due to advection are extremely slow. Diffusion tends to increase the nonreactive contaminant ion velocity compared to that predicted by advective flow theories. Movement by diffusion, in general, is still very slow.

Diffusion rates are controlled by the diffusion coefficient for the specific chemical or grouping of chemicals. This will vary over a narrow range for a specific chemical/soil combination. Different chemicals in the same soil type will have different diffusion characteristics. The diffusion rates will also be related to the particular chemical characteristics and chemical gradient, and the concentration change of the chemical with time at its source.

As with advection, predicted contaminant velocities will tend to be on the high side since diffusion theories applied in such predictions do not include a chemical and biochemical retardation factor. Chemical and biochemical processes tend to retard ion movement resulting in lower actual contaminant velocities.

3.3 HYDROGEOLOGIC SETTING:

Our analysis of contaminant movement in various geologic materials shows that:

- advection is the dominant contaminant transport mechanism for nonreactive ions when ground water velocities are moderate to rapid. These velocities are associated with permeable to moderately

permeable geologic materials (i.e. sand and gravel to sandy silt till);

- mechanical dispersion is associated with advection and results in the mixing and spreading of contaminated ground water with uncontaminated ground water along the path of flow;

- molecular diffusion is the dominant contaminant transport mechanism for ions when ground water velocities are extremly slow. These velocities are associated with low permeability materials such as clay. Diffusion still results in movement of contaminants at a very slow rate;

- a number of chemical and biochemical processes which are site and contaminant specific reduce (attenuate) chemical concentrations in ground water flow systems. Clay textured geologic materials have the greatest attenuation capability.

Thus the hydrogeologic setting will dictate whether contaminant movement is by advection or molecular diffusion. For example, if the material is moderately permeable (i.e. sandy silt till etc.) or if it is fractured (weathered clay) advective flow will predominate. If the material is clay-textured, diffusion will control contaminant transport. Additional complexities are introduced under field conditions where more than one geologic unit is present (stratigraphic layering). In these environments the interrelationships of the various stratigraphic layers will determine the mechanisms of

contaminant transport. For example if three stratigraphic layers exist at any particular location and all three layers are clay-textured, diffusion will control the movement of contaminants through all three layers. However, if a large continuous sand layer is sandwiched between two clay layers, where water flows occur through the sand, diffusion would control the movement of contaminants into the sand and then advective flow would control contaminant movement within the sand layer itself.

Surface clay soils in Ontario are weathered and fractured. Contaminants would move via this near surface fracture system with some diffusion into the soil mass and with dispersion. Competent clays to depth below this surface zone are related to the diffusion system described earlier.

4.0 RECOMMENDATIONS:

a) Based only on geologic and hydrogeologic factors, those areas of the Golden Horseshoe that are expected to be underlain by the thickest deposits of uniform fine-textured soils should be given the highest priority for the siting of all facilities.

b) Those areas of the Golden Horseshoe suspected to be underlain by coarser-textured soils or where

the geology (stratigraphic relationships) is complex should only be considered for potential siting of facilities if sites cannot be found in those areas underlain by deep, fine-textured soils.

c) Mapping in the Golden Horseshoe should first identify those large regions suspected to be underlain by deep, uniform, fine-textured soils, and those regions should have the highest priority for further study.

d) Within the high priority areas, as identified in c), further mapping should be used to provide a description of the geologic materials, their continuity and stratigraphic relationships with depth, and a discussion of the significance of these materials with respect to containing potential contaminants.

e) For the siting of an engineered landfill, areas with soil thicknesses of less than about 10 m of fine-textured soils should not be considered for an engineered landfill. A higher degree of confidence in siting such a facility would be realized as soil thickness increases. For example areas underlain by over 20 m± of fine-textured soils should be considered first over areas with lesser thicknesses of such soils.

f) For the siting of the treatment facility, incinerator and transfer stations:

   i) areas underlain by less than about 10 m of fine-textured soils can be considered, but

more detailed site specific investigations would be required to even evaluate the preliminary adequacy of the site;

ii) areas of suspected coarser-textured soils should only be considered in the event that sites cannot be chosen in the fine-textured soil areas.

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